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Sunburn Risk Among Children and Outdoor Workers in South Africa and Reunion Island Coastal Sites

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ABSTRACT

To estimate potential sunburn risk for schoolchildren and outdoor workers, ground-based ambient solar ultraviolet radiation (UVR) measurements were converted into possible child (5% of ambient solar UVR) and outdoor worker (20% of ambient solar UVR) solar UVR exposures by skin type and season for three coastal sites: Durban, Cape Point (South Africa) and Saint Denis (Reunion Island, France). Cumulative daily ambient solar UVR levels were relatively high at all sites, especially during summer, with maximum values of about 67, 57 and 74 Standard Erythemal Dose (SED) (1 SED = 100 J m^{-2}) at Durban, Cape Point and Saint Denis respectively. Sunburn risk was evident for both children and outdoor workers, especially those with skin types I and II (extremely to moderately sensitive) during summer, early autumn and/or late spring at all three sites. Although results need to be verified with real-time, instantaneous and nonintegrated personal solar UVR measurements, this understanding of sunburn risk is useful for initiating the development skin cancer prevention and sun protection awareness campaigns in both countries.

INTRODUCTION

Spending time outdoors is a common habit of many populations living in subtropical and tropical climates, such as in South Africa and on Reunion Island, France. Their climates are mostly mild to warm, conducive for outdoor recreational activities and convenient for outdoor work tasks. While spending some time outdoors is beneficial for human health, *i.e.* it promotes vitamin D production and gives a feeling of well-being, excess personal solar ultraviolet radiation (UVR) exposure has adverse impacts on human health. Sunburn and skin cancer, *i.e.* nonmelanoma and melanoma skin cancers, are the two most commonly experienced negative effects. Nonmelanoma skin cancers are disfiguring and painful yet nonfatal. Melanoma skin cancers are fatal if not detected sufficiently early for treatment.

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Statistics for South Africa and Reunion Island suggest that the incidence of melanoma skin cancer for both sexes combined is approximately 6.2 and 0.9 (age-standardized rate per 100 000 people per year—a rate independent of population age composition) respectively (1). The large difference in melanoma incidence between the two countries may be due to differences in skin type, timing and duration of time spent outdoors and use of sun protection. Sunburn is an important risk factor for skin cancer, although the relationship between sun exposure, sunburn and skin cancer is complex (2,3). Chronic sun exposure is generally associated with nonmelanoma skin cancers, *i.e.* basal cell and squamous cell carcinomas, while the relationship between melanoma and sun exposure is complicated, but acute exposure may be more risky. Melanin in the skin affords an individual some natural protection against sunburn, depending on the melanin amount and skin type (Table 1). Individuals with minimum natural protection, *i.e.* skin phototypes I and II, as well as individuals spending extended periods of time outdoors without sufficient sun protection, are at risk of sunburn.

Schoolchildren and outdoors workers are two population groups at risk of spending excess periods of time outdoors and therefore of experiencing sunburn. Several studies have noted sunburn prevalence among children and outdoor workers. In a New Zealand study (4), 63.7% of primary schoolchildren who were surveyed reported that they had experienced sunburn the previous summer. Similarly, 67% of Swedish children (a sample between 4 and 7 years of age) had been sunburnt (5). Studies have shown that outdoor workers also experience the adverse health impacts from excess solar UVR exposure. In Switzerland, between 12 000 and 15 000 nonmelanoma cases are reported annually including outdoor agricultural workers, especially on the head and neck sites (6). Ocular cancer is also a concern among outdoor workers. In Sweden and Australia, several outdoor workers have had eye tumors or ocular melanoma due to excess solar UVR exposure (7,8). Even though occupational standards for indoor UVR exposure from machinery such as arc welding equipment exist, no standards or safety limits are defined for outdoor solar UVR exposure for outdoor workers, or for children.

The World Health Organization emphasizes sun protection use among children (9) and outdoor workers (10) given the known nature of their exposures. Children attending school may

Table 1. Skin phototype classification with solar UVR exposure estimates likely to cause sunburn on untanned skin (adapted from Fitzpatrick, 1988 [38]).

Skin type Unexposed skin color UV radiation sensitivity	Constitutive characteristics	History of sunburn	Continuous UV radiation exposure estimated to elicit sunburn on untanned skin (SED*)
I White Extremely sensitive	Fair skin, blue or light eyes and freckles	Always burns on minimal exposure	2–3
II White Very sensitive	Red or blonde hair, blue, hazel or brown eyes and freckles	Burns very readily, freckles common	2.5–3
III White or light brown Moderately sensitive	Brown hair and blue, hazel or brown eyes	May burn on regular exposure with no protection, tans slowly	3–5
IV Light brown Relatively tolerant to UVR	Brown hair and dark eyes	Burns rarely, tans rapidly with minimal exposure	4.5–6
V Brown Variable	Brown eyes and dark brown or black hair	Despite pigment, may burn easily on exposure	6–20
VI Black Relatively insensitive	Brown eyes and dark brown or black hair	Rarely burns, though sunburn is difficult to detect on heavily pigmented skin	6–20

spend time outdoors during school breaks and extracurricular activities which often occur during peak solar UVR hours, *i.e.* between 1000 h and 1500 h. Outdoor workers may regularly spend prolonged periods of time outdoors and may not always effectively apply the appropriate personal protective equipment (11). Studies have found that schoolchildren and outdoor workers may receive about 5% and 20% of the total daily ambient solar UVR received on a horizontal surface respectively. Indeed, in a rudimentary South African study, children received *ca* 5% of the total daily ambient solar UVR (12), a finding consistent with similar studies among schoolchildren in New Zealand (4), Denmark (13) and England (14).

Several factors may influence this percentage of the ambient received by children and outdoor workers including type of activity, anatomical attachment site of the personal UVR dosimeter, local ambient solar UVR and temperature levels (affecting comfort levels and the choice to spend time outdoors) and personal sun protection practices. Previous studies found that outdoor workers in various countries received about 10–70% (15) of the total daily ambient solar UVR depending on the amount of work time spent outdoors; the anatomical site of measurement may vary this percentage from 11% (on the chest) (16), 24% on the back (16) and 2–17% for the eyes depending on the type of hat used and typical seasonal variations (17). Among Italian vineyard workers, for spring months, outdoor workers' backs received between 53% and 87% of ambient exposure, and arms between 30% and 60% (18). In a New Zealand personal UVR dosimetry study among outdoor workers (defined as builders, horticulturalists and road workers) monitored results showed that outdoor workers received about 20% of the total daily ambient solar UVR levels (19). This percentage was similar to that found in several other studies in Australia (20) and Germany (21) and lower than that found in Switzerland (22).

To date, no attempts have been made to empirically determine (or estimate) the nonintegrated, personal solar UVR exposure of children and outdoor workers in South Africa and Reunion Island to assess sunburn risk. In South Africa, a desktop study characterized nonmelanoma skin cancer risk for outdoor workers as being high (23) and schoolchildren's cumulative sun exposure was found to be relatively high using polysulfone film (12). Two studies have estimated sunburn risk among susceptible groups at several sites in South Africa (24,25), but no evidence of similar studies was found for Reunion Island. Nevertheless, this information is necessary to develop sun protection awareness campaigns and skin cancer interventions, particularly in countries with multiethnic populations such as South Africa and Reunion Island since ethno-racial differences in sun protection and behavior have been observed (26).

This research used ambient solar UVR data (ground-based data as primary source) to estimate possible sun exposure among children and outdoor workers living in South Africa and Reunion Island as a first step to understanding sunburn risk. This level of information is needed to develop comprehensive, country-specific strategies to minimize sun-related risks among at-risk subpopulations. The study is part of an international research association entitled "Atmospheric Research in Southern Africa and Indian Ocean" (ARSAIO) that is a collaboration between South African (National Research Foundation) and French (CNRS) researchers seeking to find answers to common atmospheric problems facing both countries. A unique aspect of this research article is the merging of atmospheric science outputs with public health messages for skin cancer prevention, public awareness and sun protection.

MATERIALS AND METHODS

Solar UVR definition. Solar radiation covers a broad wavelength range: the shorter the wavelength, the greater the radiation energy and the greater its capability to produce chemical and biological reactions. Solar UVR may be divided into three bands: UV-C, UV-B and UV-A. Most UV-C is absorbed by dioxygen and stratospheric ozone in the atmosphere and very little reaches the Earth's surface. UV-B and UV-A are more likely to reach the Earth's surface and impact upon human health. Erythemal UVR is defined as UV spectral irradiance weighted by the action spectrum for human erythema (or sunburn) (27). This quantity is a measure of the potential for biological damage due to solar UVR. Ambient solar erythemal UVR data for both South African and Reunion Island stations for 2009 were applied in this study as these annual data sets are the most recent complete sets.

Ground-based monitored ambient solar UVR data at Durban and Cape Point, South Africa. The South African Weather Service monitors ambient solar erythemal UVR levels at six stations in South Africa: Pretoria (25.7°S, 28.2°E), Durban (30.0°S, 31.0°E), Cape Town (33.98°S, 18.6°E), Cape Point (34.35°S, 18.48°E), De Aar (30.7°S, 24.0°E) and Port Elizabeth (33.9°S, 25.5°E). For this study, data collected at the Cape Point and Durban stations were used (Fig. 1). Both are coastal sites. Cape Point station is well maintained in terms of instrument calibration and consistent data collection. The Cape Point laboratory is part of the World Meteorological Organization's Global Atmosphere Watch network of stations to monitor the chemical composition of the Earth's atmosphere. The pristine environment of Cape Point enables measurements to be made in clean air that has passed over the vast Southern Ocean. The Cape Point station is located at 230 m above sea level and has a predominant wind direction of south-easterly and north-westerly during summer and winter respectively. The Durban station was located south of the city (petroleum industry location, it was relocated in 2011 north to the new airport site) and has a similar summer climate (*i.e.* hot and humid) to Reunion Island. In its original location it was located at 8 m above sea level. Durban has a predominant wind direction of north-easterly and south-westerly in summer and winter respectively.

A UV Biometer (model 501) comprising a Robertson-Berger pattern UVR detector, digital recorder and control unit is used to measure ambient solar UVR levels at the Cape Point and Durban stations. The UV-Biometer spectral response closely mimics the McKinley/Diffey erythemal action spectrum (27). Through careful and regular calibration of the broadband biometer instruments, the logged values in Minimal Erythemal Dose (MED, 1 MED = 210 Jm^{-2}) per hour are converted into units of erythemal irradiance (Wm^{-2}) (See Annexure 1 for full description) and can be expressed in terms of SED values, the international standard unit for expressing personal solar UVR exposure (defined as 1 SED = 100 Jm^{-2}) (28). Most recently, the Durban and Cape Point field instruments were intercompared with the Travelling Standard calibrated against the fast scanning spectroradiometer of the type SPECTRO 320D NO 15 at Deutscher Wetterdienst Meteorologisches and thereby have traceability to the International Bureau of Weights and Measures (BIPM). The preliminary results found that the difference in the measurement before and after calibration is less than 4%.

Ground-based monitored ambient solar UVR data at Saint Denis, Reunion Island. A UV spectroradiometer is used at the Observatory of Atmospheric Physics at Reunion to measure ambient solar UVR levels. The instrument is a double-monochromator Bentham DTMc-300F located at Saint Denis (20.9°S, 55.5°E, 85 m above sea level). The solar radiations are received by a Teflon diffuser under a quartz dome. The 10 m optical fiber cable relays the diffuser to the monochromator. Spectral measurements are performed every 15 min in the 280–400 nm wavelength range, with a 0.5 nm step, the scan duration is about 4 min. The instrument is regularly calibrated with a reference lamp (for 2009 measurement it was a CL6-150 W, provided by the Bentham company) traceable to NIST (National Institute of Standards and Technology). In the UVB range the irradiance expanded uncertainty (coverage factor $k = 2$) is about 8%. Irradiance measurements are converted into hourly SED values, thus 8% uncertainty is expected on SED.

Possible child and outdoor worker solar UVR exposure and sunburn risk calculations. To provide an estimate of the annual variation in child solar UVR exposure at Cape Point, Durban and Saint Denis, the factor of 5% was applied to the daily ambient ground-based solar erythemal UVR measured at each station for a typical year (in this case the year 2009), according to the previous studies described in the introduction. Potential outdoor worker solar UVR exposure was defined as 20% of the measured total daily ambient solar UVR levels. The rationale for selecting 5% and 20% was a conservative, median estimate of all studies cited in the introduction. This percentage may be higher or lower for specific outdoor occupation types or different anatomic sites. Possible child and outdoor worker solar UVR exposures were calculated for Cape Point, Durban and Saint Denis. Seasonal trends in possible solar UVR exposure patterns among children and outdoor workers are described. Southern Hemisphere summer, autumn, winter and spring were defined by the months of December, January and February; March, April and May; June, July and August; and September, October and November respectively.

The risk of sunburn, an indication of excess sun exposure and associated in skin cancer etiology, has been defined by skin type (Table 1). This risk was overlaid onto the quantified child and outdoor worker solar UVR exposures to provide an indication of exposure and, subsequently, the health risk of sunburn. By superimposing the minimal amount of solar UVR exposure required to elicit sunburn response for different skin types onto the annual variation in child and outdoor workers' solar UVR exposure, the number of days during 1 year when a child or an outdoor

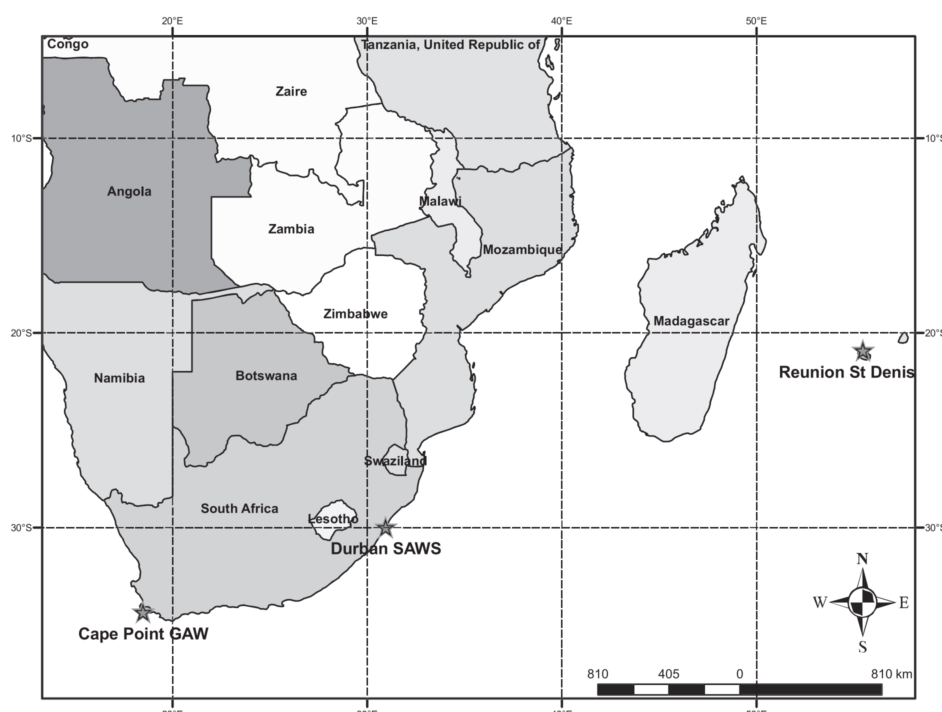

Figure 1. Location of the three solar UVR stations used in this study.

worker of a particular skin type may be at risk of sunburn was estimated. Since some outdoor workers, such as farmers, work 7 days per week, weekdays, weekend days and public holidays were included. For schoolchildren, all days were included since children may spend time outdoors on weekend days for sports and extracurricular activities. No individuals were involved in this study and only hypothetical scenarios were applied.

RESULTS

Ground-based total daily ambient solar UVR levels

Figure 2 shows the mean and median seasonal variation in total ambient solar UVR levels (SED units) at Durban, Cape Point and Saint Denis. Total ambient solar erythemal UVR levels were relatively high for Durban, Cape Point and Saint Denis, with maximum values recorded during summer of 67, 57 and 74 SEDs respectively (Fig. 2). There were more missing data for Durban and Saint Denis (Durban during summer had 28 missing days, during spring 2 days; Saint Denis during summer had 42 missing days, during spring 4 days and during autumn 25 days, no missing data for Cape Point). The missing data might have caused the observed large standard deviations for the respective station.

Figure 3 shows the ground-based monitoring station results for total daily ambient solar UVR for Cape Point, Durban and Saint Denis during 2009. The typical envelope pattern of solar UVR intensity in the Southern Hemisphere is evident with higher levels during summer (December, January and February) and lower levels during winter (June, July and August). The scatter below the envelope is indicative of factors influencing the level of solar UVR at the surface, and in these instances, it is most likely cloud cover and aerosols (*e.g.* sea salt spray, air pollution, smoke etc.) which vary more readily temporally than stratospheric ozone which also has an influence on surface solar UVR levels. The difference in solar UVR levels of Cape Point and Durban *vs* Saint Denis is mainly due to latitude difference, as Saint Denis is located at lower latitude than the two South African sites.

Pattern of total daily solar UVR exposures among children and outdoor workers

Potential total daily solar UVR exposures for children and outdoor workers are shown in Fig. 4. Sunburn risk is overlaid, highlighting the required solar UVR exposure needed to elicit sunburn by skin type (Table 1). For example, for a child with a skin type II (moderately sensitive), continuous exposure of between 2.5 and 3 SED units may cause sunburn in the three locations at the beginning and at the end of the year, but of course it depends on bodily orientation, applied sun protection, activity undertaken etc. As expected, the general pattern of child and outdoor worker solar UVR exposure follows the typical seasonal trends with higher levels of solar UVR exposure during summer, early autumn and late spring.

The risk of sunburn for children with skin types I, II and III, given their potential total daily solar UVR exposure, was mainly present during summer and greatest for children living in Saint Denis, followed by Durban and Cape Point, explained mainly by latitude effects. There was little to no risk of children with skin types of IV, V and VI experiencing sunburn, based on the weighting of 5% of the total daily ambient solar UVR exposure. The risk of sunburn for outdoor workers, given their potential total daily solar UVR exposure, was present during almost all seasons (excluding midwinter) and greatest for outdoor workers living in Saint Denis, followed by Durban and Cape Point, again explained mainly by latitude effects. Outdoor workers with skin types I, II, III, IV and V were at risk of sunburn on at least 1 day and in most cases more than several days during the year in all places when applying the weighting of 20% of the total daily ambient solar UVR exposure.

Number of days that children and outdoor workers may be at risk of sunburn by place, season and skin type

Table 2 shows the total number of days per year and for each season that children and outdoor workers may be at risk of

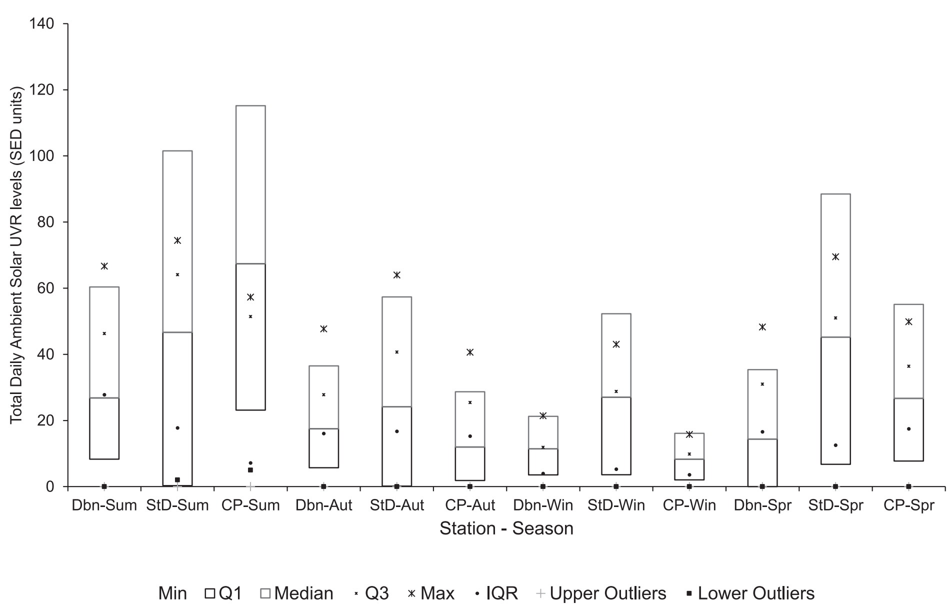

Figure 2. Total daily ambient solar UVR levels at the three monitoring stations Durban (Dbn), Saint Denis (StD) and Cape Point (CP) for summer (Sum), autumn (Aut), winter (Win) and spring (Spr). (Min = minimum value; Q1 = first quartile; Q3 = third quartile; IQR = interquartile range).

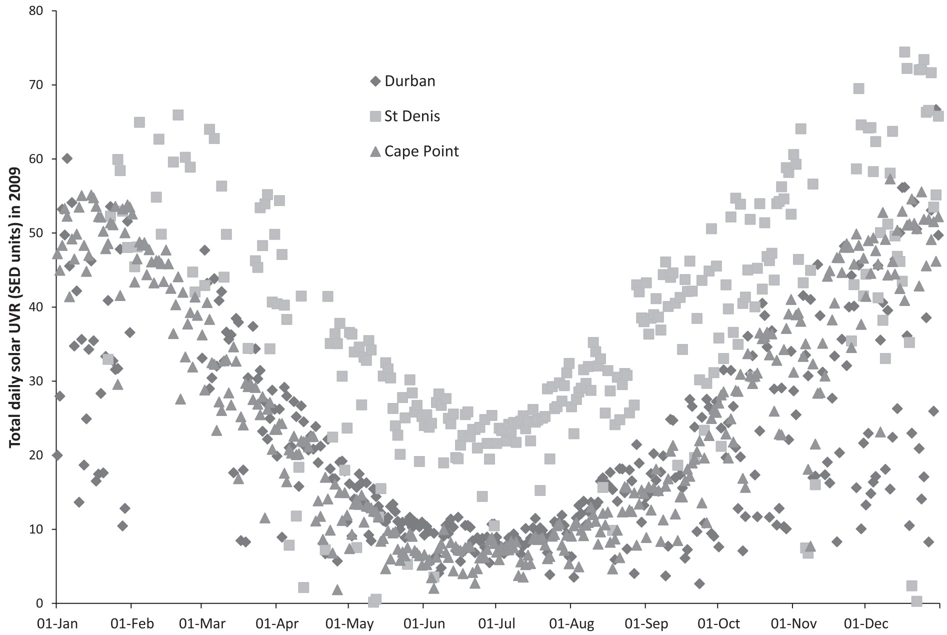

Figure 3. Ground-based total daily ambient solar UVR levels for Cape Point, Durban and Saint Denis (SED units).

sunburn for Durban, Cape Point and Saint Denis by skin type. For example a child living in Saint Denis with skin type II may experience 30 days during summer when he/she may be at risk of sunburn if he/she experience approximately 5% of the total daily ambient solar UVR. Overall, children living in Saint Denis with skin types I, II and III may be at risk of sunburn throughout all seasons, excluding winter. Children living in Durban and Cape Point with skin types I, II and III may be at risk of sunburn mainly in the summer months and with fewer risk days during autumn and spring. No child with skin types IV, V and VI in any of the three places is likely to be at risk of experiencing sunburn during any season, where the actual risk depends on the actual duration of exposure (*i.e.* if an individual child's exposure is greater than the hypothesized 5% of the total daily ambient solar UVR levels, exposure would be greater for that child), use of sun protection, body position, timing and duration of exposure and type of activity.

Outdoor workers of varying skin types in Saint Denis may be at risk of experiencing sunburn throughout all seasons, including during winter months. Similarly, for outdoor workers in Durban and Cape Point, the risk of sunburn is evident across all skin types and seasons except for skin types IV, V and VI during winter months. The melanin content in the skin of outdoor workers with these skin types would provide protection against the relatively lower ambient solar UVR levels during winter months (29). The number of days that outdoor workers may be at risk of experiencing sunburn in all three places tended to be greater during spring than autumn months, possibly indicative of the effects of total column ozone on surface solar UVR levels as ozone poor air may move away from Antarctica over southern hemisphere countries during spring (30).

DISCUSSION

This study is aimed to estimate the sunburn risk between two susceptible population groups, *i.e.* children and outdoor workers, in South Africa and Reunion Island (countries with multiethnic populations) to inform sun awareness campaign development. The quantification of their real-time, nonintegrated personal solar UVR exposures is the ideal method to identify risk factors and help design sun awareness and risk reduction programmes. However, such studies are expensive and labor intensive, hence an alternative study of the national risk of sunburn, as a proxy for skin cancer risk, was carried out here as a first step. Although skin cancer rates appear to be relatively low in both countries, sun exposure is associated with other adverse health effects including cataracts and immune suppression. Hence, understanding sunburn risk as a proxy for a range of adverse health effects from excess sun exposure is important.

An analysis of the solar UVR environment in both countries showed that total daily ambient solar UVR levels were relatively high at all three local sites of Saint Denis, Durban and Cape Point. Highest levels were recorded during the Southern Hemisphere summer, followed by spring, autumn and winter. A latitudinal gradient existed among the three sites where Saint Denis at the lowest latitude received the highest solar UVR levels and Cape Point at the highest latitude received the lowest solar UVR levels, as expected. Similar latitudinal differences have been found in Chile which is a country that spans 18–53°South (31).

Potential total daily solar UVR exposures were calculated for children and outdoor workers in Cape Point, Durban and Saint Denis and sunburn risk by skin type was overlaid. While the general pattern of child and outdoor worker exposure followed the typical seasonal trends in ambient solar UVR, an important conclusion was highlighted: child and outdoor worker exposure levels may be high during spring and autumn, not only in summer. Public health awareness campaigns to advise against excess sun exposure and to promote sun protection usually run during summer months when solar UVR levels are typically at their highest. From the results presented here, such campaigns targeting schoolchildren and outdoor workers may prove beneficial if they were extended beyond the summer months to include

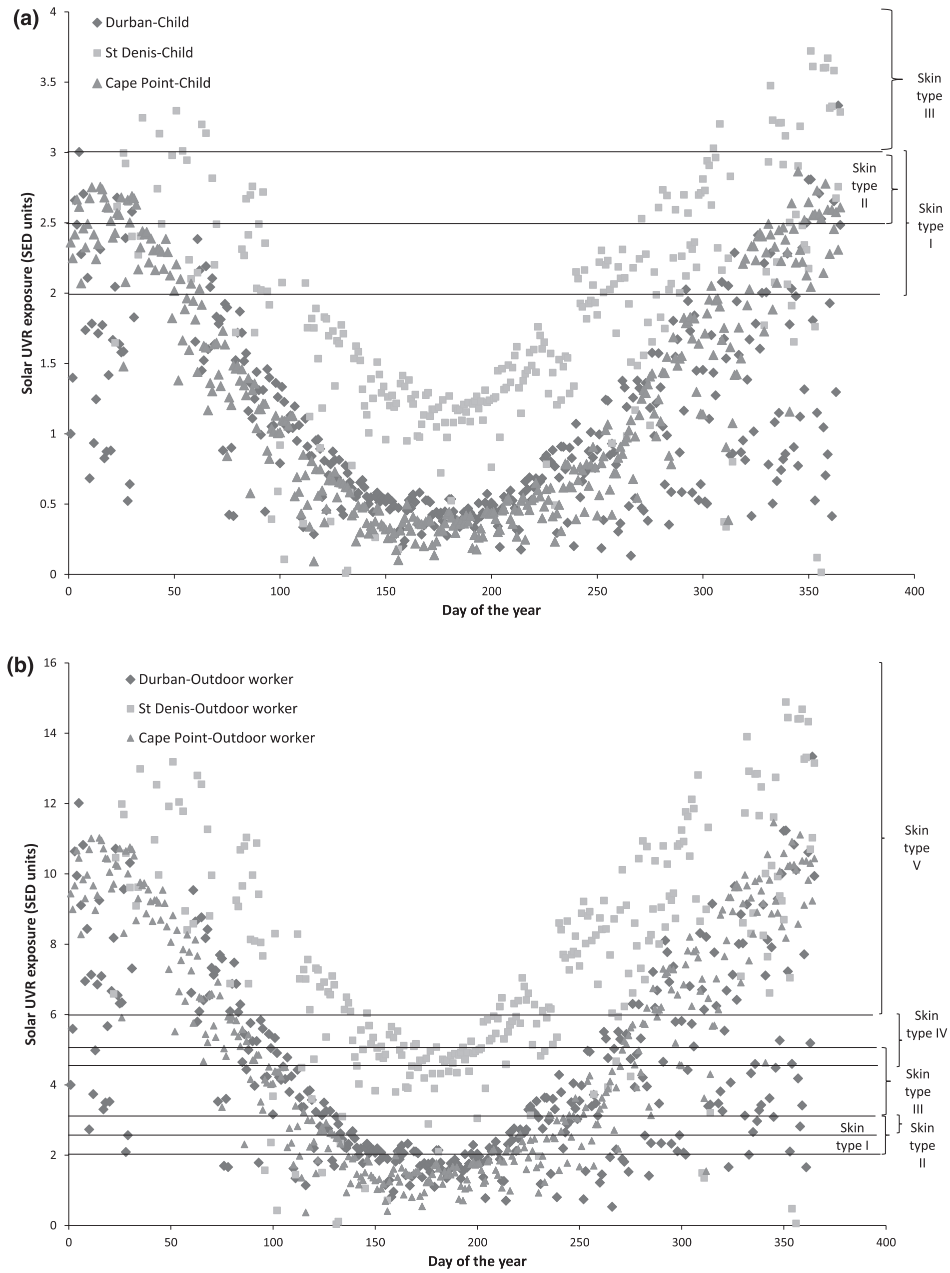

Figure 4. Potential total daily (a) child and (b) outdoor worker solar UVR exposure (SED units).

autumn and spring when solar UVR levels may still be considerably high, especially in Saint Denis and Durban. This is especially the case for sun protection and skin cancer prevention programmes targeting outdoor workers in Saint Denis.

When considering the role of skin type, the risk of sunburn was greatest among children with more fair skin types, *i.e.* skin types I, II and III. This is to some extent expected given the lower levels of melanin in skin of these skin types but actual risk would depend on several factors besides exposure duration. Among more than 10 000 White (at least skin types I and II) German preschool children, subjects with a reported history of increased sun exposure, *i.e.* painful sunburns, had significantly higher nevus counts than individuals without these characteristics (32). Melanocytic nevi occurrence and number have been associated with melanoma skin cancer etiology (33). These nevi may increase in number as children age, and may be linked with sunburn which has also been shown to increase with age, as was the case in a study of European children where sunburn incidence increased from 1% to 23% between the ages of 1 and 6 years (34). Skin type and presence of melanocytic nevi should both be considered by health care providers for individual and personally tailored sun protection advice in South Africa and Reunion Island.

Using ambient solar UVR levels and crude weightings derived from previous studies, an estimate of child and outdoor worker's personal solar UVR exposure was made. There are several limitations of this approach over personal solar UVR measurements and include that generalized weightings inhibit the broad range in individual exposures usually seen in personal dosimetry studies. Moreover, every day of the year was treated as a school/work day when some days may be weekend days and holidays, therefore

Table 2. Total number of days per year and per season that children and outdoor workers of varying skin types may be at risk of experiencing sunburn from solar UVR exposure depending on activity, sun protection etc., using an estimated personal exposure of 5% and 20% of the total daily ambient solar UVR levels respectively.

Site	Skin type I					Skin type II					Skin type III					Skin type IV					Skin types V and VI				
	Total	Sum	Aut	Win	Spr	Total	Sum	Aut	Win	Spr	Total	Sum	Aut	Win	Spr	Total	Sum	Aut	Win	Spr	Total	Sum	Aut	Win	Spr
Children																									
Cape Point	96	81	1	0	14	32	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Durban	36	22	5	0	9	11	11	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
St Denis	117	42	20	2	53	58	30	7	0	21	23	17	2	0	4	0	0	0	0	0	0	0	0	0	0
Outdoor workers																									
Cape Point	266	90	68	21	87	241	90	59	8	84	221	90	48	3	80	182	90	33	0	58	137	87	9	0	41
Durban	266	61	82	45	78	216	59	66	21	70	192	54	60	12	66	120	42	35	0	43	80	35	20	0	25
St Denis	270	46	60	89	75	267	46	58	88	75	266	46	58	87	75	241	46	52	72	71	172	46	41	16	69

Note Sum = summer (December, January and February); Aut = autumn (March, April and May); Win = winter (June, July and August); and Spr = spring (September, October and November).

results are not cumulated and totaled to give an annual exposure estimate and instead are only considered on a daily basis.

Outdoor workers are particularly susceptible to chronic sun exposure. Considerable numbers of outdoor workers have been found to have sun sensitive skin types (35,36). A systematic review of cross-sectional and interventional studies found that sunburn rates among outdoor workers ranged from 50% to 80% (36). In this assessment, all outdoor workers with skin types I to V were at risk of sunburn in both countries at least once during the year (usually several risk days were evident especially for outdoor workers with fairer skin types), and not only during summer months. Generally, inadequate sun protection is used by outdoor workers (36) increasing the chance of sunburn occurrence. Ethno-racial differences have been noted among outdoor workers for sunscreen and sunglasses use (26). Sun protection behaviors among outdoor workers in South Africa and Reunion have not been estimated. Given that occupational sun safety education may be effective in increasing outdoor workers' sun protection behaviors(36) and thereby decreasing sunburn rates, health promotion messages targeting outdoor workers tailored with skin type–related advice may prove useful in South Africa and Reunion Island, and other countries at similar latitudes in both northern and southern hemispheres.

In conclusion, Although childhood and outdoor occupation are important life periods in terms of sun protection, a meta-analysis of sunburn and risk of melanoma found that risk increased with increasing number of sunburns during all life periods(37) and that prevention efforts should focus on reducing sunburns during all stages of life. In principal this may be effective, except that sun protection campaigns have been complex to administer because it is not possible to create one, simple message for all subpopulation groups. A targeted approach focused on a specific population group, age range, activity or environment is usually preferred. Skin type may need to be an additional criterion considered when developing sun protection messages in countries such as South Africa and Reunion Island where multiethnic populations are found.

ANNEXURE 1

Using equation

$$E(\mathrm{W\ m^{-2}})_{\mathrm{ER}} = (U - U_{\mathrm{offset}}) \times f_n(\mathrm{SZA}, \mathrm{O_3}) \times C_{\mathrm{CAL}} \times C_{\mathrm{COS(SZA)}} \times C_T,$$

where E (W m^{-2})$_{ER}$: erythemal irradiance; U (logger reading): reading of logger reading at 1 min integration time steps; U_{offset} (logger reading): offset (*e.g.* logger reading during hours of darkness); f_n: calibration matrix (normalized to 1 at SZA = 40° and O_3 = 300 DU); C_{CAL} ((W m^{-2})$_{ER}$/logger reading): calibration factor; $C_{COS(SZA)}$: cosine correction factor; C_T: temperature correction factor.

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